AD 275 441

FPR-003
ISSUE NO. 1
MAY 1962

COMPILATION OF UNPUBLISHED MATERIALS INFORMATION

FIRST PHASE II REPORT

14 NOVEMBER 1961 THROUGH 15 MAY 1962

BY: J. M. SHULTS

CONTRACT NO.
AF33(657)-7248

GENERAL DYNAMICS | FORT WORTH

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PHASE II PROGRESS REPORT

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By: J. M. Shults
J. M. Shults

APPROVED BY: D. C. Wilson
D. C. Wilson
Project Manager

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AF33(657)-7248

The work reported in this document was sponsored by:
Aeronautical Systems Division
Air Force Systems
United States Air Force

ABSTRACT

The progress report covers the work accomplished during the period 14 November 1961 through 15 May 1962. It consists of the preparation of brief reports on each item of material and processes work in progress at General Dynamics/Fort Worth during the reporting period. Each report contains a brief descritpion of the objective, a discussion of the program, and results and conclusions if available. Reports on 28 different programs are included.

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INTRODUCTION

This is the first semi-annual Phase II report on Contract AF33(657)-7248 entered into on 14 November 1961 between General Dynamis Corporation (General Dynamics/Fort Worth Division) and the United States of America. The contract is an engineering services type contract under the supervision of the Aeronautical Systems Division, Air Force Systems Command, United States Air Force. The principal objective is to supply information on company conducted unpublished materials research and development programs generated by General Dynamics/Fort Worth, Fort Worth, Texas. This includes reviews of materials efforts in progress and the compilation of these and past data.

The project is separated into two phases as indicated below:

<u>Phase I</u> - This phase consists of the compilation of previously unreported data generated by General Dynamics/Fort Worth both under corporate sponsorship and government subsidized. This data is to be published and distributed to an approved distribution list furnished by the ASD Technical Monitor (ASRCEM-1).

<u>Phase II</u>- This phase consists of a semi-annual review of materials research and development efforts in progress at General Dynamics/Fort Worth and the compilation of the data in a report to provide timely information on materials work that is not readily available.

DISCUSSION

Phase II of this contract consists of the preparation of short summary type reports on each item of current materials or processing research and development in progress at General Dynamics/Fort Worth. Each report is divided into four sections as follows:

A. Title - Complete title as it will appear on the GD/FW final report.

B. Objective - A brief statement as to the objectives and/or purposes of the test programs.

C. Discussion - A brief discussion of the program is given including the general test plan and methods to be used in reaching the objectives of the program.

D. Results - Results and conclusions are given where available.

In addition an identifying number has been assigned each report and the funding method indicated along with the estimated completion date.

A number of research and development programs on materials and processes are now in progress at GD/FW. These programs are in various stages of progress some being near completion while others have just been started. A report on each of these individual programs is included, even when test results and conclusions are not available, in order to show the areas of materials and processes that are being researched.

TR 30-3020 (Funded under the B-58 Contract)

TITLE: High Strength Steels - 9% Nickel and 18% Nickel Alloys - Evaluation of

OBJECTIVE: The purpose of this program is to fully evaluate two new alloy systems (the 9% nickel alloy and the 18% nickel-8% cobalt alloy system), and to obtain sufficient data on these alloys at very high strength levels so that a comparison can be made with two currently used high strength steels (4340 and H-11 tool steel).

DISCUSSION: The following items are to be covered in this program:

1. Heat treat response of the two alloys will be investigated to determine optimum heat treat cycle, depth of hardenability, etc.

2. Stress corrosion tests will be run in 5% salt solution with alternating air dry cycle.

3. Fatigue data will be obtained to establish S-N curves for $K_T = 1$ and $K_T = 2$.

4. The above tests will be run on material from forgings of approximately 6" diameter forged on a set of existing dies under production conditions.

5. Fracture or notch toughness will be determined on specimens 0.180" thick with $K_T \cong 17.0$. These specimens are to be made from 4" x 12" billet material.

6. Weldability of these alloys will be conducted by Menasco Mfg. Co. (Hurst, Texas) on the Uniweld machine and weld strength will be determined.

7. Electron fractography and microscopy studies will be run on fractured specimens.

RESULTS: The results obtained to date in this program are shown in the attached tables:

Table I: Tensile Properties of SAE 4340 (Various Melt Process) and 9 Ni-4Co Alloy.
Table II: Fracture Toughness Properties of SAE 4340 (Various Melt Processes) and 9 Ni-4Co Alloy.
Table III: Heat Treat Response of 9 Ni-4Co and 18 Nickel Steels (Material from 6" Diameter Forging)

ESTIMATED COMPLETION DATE: October 1962.

TR 30-3020 (Continued)

TABLE I

TENSILE PROPERTIES OF SAE 4340 (VARIOUS MELT PROCESSES) AND 9 NI-4CO ALLOY

MATERIAL	TEMPER* °F	0.2% YIELD STRENGTH KSI	ULT. TENSILE STRENGTH KSI	% ELONG. IN 2"
9 Ni-4Co Steel Dbl. Vac. Melt	400°F	222.5	279.3	9.0
4340 Air Melt	400°F	222.1	282.2	5.5
4340 Air Melt	750°F	170.5	181.2	10.0
4340 Air Melt	1050°F	149.7	163.1	12.0
4340 Air Melt Vac. Remelt	400°F	216.3	286.2	9.5
*Double tempered at indicated temperature				

NOTE: Specimens were 0.180" thick; all machining and heat treatment performed by Republic Steel Research Center.

TABLE II

FRACTURE TOUGHNESS PROPERTIES OF SAE 4340 (VARIOUS METL PROCESSES O AND 9 NI-4CO ALLOY

MATERIAL	TEST TEMP °F	NOM. NOTCH STRENGTH KSI	NET NOTCH STRENGTH KSI	% SHEAR	AVG.HARD-NESS R'c'
9 Ni 4Co Steel Dbl. Vac.Melt Dbl.Temper @ 400°F	-65	96.6	-	50.8	52.2
4340 Air Melt Dbl. Temper @ 400°F	-65 RT	56.1 64.8	- 103.7	11.8 23.5	51.9 50.5
4340 Air Melt Dbl. Temper @ 750°F	-65 RT	67.3 118.8	- 208.9	15.8 97.6	45.0 44.0
4340 Air Melt Dbl Temp @ 1050°F	-65 RT	156.9 150.4	- 193.3	100 100	35.4 34.6
4340 Air Melt. Vac. Remelt, Dbl. Temper @ 400°F	-65 RT	60.6 76.3	- 102.9	13.7 38.1	54.0 54.0

NOTE: Specimens 0.180" thick with precrack center notch ($K_T \cong 17$). All specimens machined and heat treated by Republic Steel Research Center.

TR 30-3020 (Continued)

TABLE III
HEAT TREAT RESPONSE OF 9 NI-4CO AND 18 NICKEL STEELS (MATERIAL FROM 6" DIA. FORGING)

MATERIAL	HARDEN. TEMP. (°F)	DRAW TEMPER (°F)	FTY KSI	FTU KSI	% ELONG. IN 4D	% R. A.	NOTCH ULT. KSI	NOTCH/UNNOTCH RATIO	K_T FACTOR
9% Ni-4%Co Steel	1450	400	227.8	274.0	13.0	41.0	294.4	1.07	5.7
		450	226.9	271.1	11.0	41.6	316.8	1.17	5.7
		500	221.4	256.6	11.0	39.0	287.7	1.12	5.7
		550	221.7	248.6	11.0	44.8	291.8	1.17	5.7
	1500	400	225.3	284.2	10.0	35.5	259.2	0.91	6.9
		450	222.6	275.2	11.0	38.2	288.6	1.05	5.7
		500	219.5	256.0	11.5	45.4	292.0	1.14	6.9
		550	219.6	250.4	10.0	34.0	268.8	1.07	6.9
	1550	400	187.2	283.4	12.5	39.5	281.8	0.99	6.9
		450	219.9	267.7	13.0	48.7	292.4	1.09	5.7
		500	213.4	255.8	12.5	39.7	297.7	1.16	5.7
		550	214.2	248.0	11.0	38.4	292.6	1.18	5.1
18% Nickel Steel	1500	850-1 Hr	228.8	245.4	10.5	51.5	345.2	1.41	5.7
		-3 Hr	246.4	263.6	11.0	50.1	360.0	1.37	6.3
		-6 Hr	255.6	269.8	9.0	45.2	369.6	1.37	5.7
	1500	900-1 Hr	241.3	255.6	10.5	57.8	366.5	1.43	5.9
		-3 Hr	261.3	278.7	9.0	44.8	358.4	1.29	5.7
		-6 Hr	275.1	286.0	8.0	43.8	361.2	1.26	6.2
	1500	950-1 Hr	276.4	284 6	9.0	46.1	360.4	1.27	5.7
		-3 Hr	275.2	286.2	10.0	49.3	323.2	1.13	5.7
		-6 Hr	282.4	290.1	8.0	45.2	317.8	1.10	5.7
	1500*	900-3 Hr*	265.2	306.0	10.0	51.5	360.1	1.18	5.7

*Quenched @ -112°F for 16 Hours prior to aging.

TR 30-2007 (Funded Under the B-58 Contract)

TITLE: Materials - 4340 Alloy Steel - Stress Corrosion and Effects of Banding, Literature Survey

OBJECTIVE: To conduct a literature survey on 4340 alloy steel in the fields of stress corrosion cracking and effects of banding.

DISCUSSION: These surveys are being conducted as a results of an informal ASD request following service failures on air melt 4340 steel alloy. The exact reason for the failures has not been determined but the type of failure is indicative of stress corrosion cracking. A purported improvement might be the use of vacuum melted 4340.

The second part of this program stems from the fact that the proposed use of vacuum melted 4340 alloy steels poses another unknown. A joint survey by GD/FW and ASD indicates that all such steel is banded to some degree. The effects, if any, of banding on the mechanical properties is not yet known.

RESULTS: The literature survey on stress corrosion has been completed and the report is presently being prepared. All known data on banding has been collected and metallurgical analyzation will begin.

ESTIMATED COMPLETION DATE: September 1962.

TR 30-1946 (Corporate Funded)

TITLE: Process - Hydrogen Embrittlement of Cadmium Plated Alloy Steels - Notch Tensile Specimens - Sustained Load Testing of (ARTC Project 6-61).

OBJECTIVE: To establish a short time test method for accurately determining hydrogen embrittlement in alloy steels.

DISCUSSION: Approximately fifteen (15) companies are involved in an AIA sponsored program, "Evaluation of Cadmium Plating Systems for Hydrogen Embrittlement". This program represents GD/FW participation.

The program is being conducted as follows:

1. Five (5) adapter assemblies for attaching notch tensile specimens to existing Arcweld stress rupture machines will be fabricated.

2. Alignment of the adapter assemblies will be checked using Boeing supplied alignment cell to insure that bending stresses do not exceed 3% of axial stresses in the 3600 to 8000 pound range.

3. Stress rupture tests will be conducted on cadmium plated notch tensile specimens. Test will compare a special Boeing plating bath to the Dalic brush plating process.

RESULTS: The adapter assemblies are in the process of being fabricated. Upon completion, these will be checked for alignment and the program will be conducted as noted above.

ESTIMATED COMPLETION DATE: September 1962.

TR 30-0839 (Funded under the B-58 Contract)

TITLE: Material - RS-140 Titanium - Form-Aging Studies of

OBJECTIVE: The purpose of this test program is to determine the relation between the parameters of time, temperature, and percent stretch on the tensile and compressive properties of RS140 titanium alloy when formed and heat treated simultaneously by a process referred to as "form-aging".

DISCUSSION: The aging response of this alloy in sheet gages is quite rapid and if forming processes are properly controlled, (i.e., time-temperature-percent stretch) the material can be formed and aged simultaneously thereby eliminating the usual aging cycle with its requirements for fixtures, atmospheric control, etc. It is known, however, that such processes may reduce compressive strength due to the phenomenon known as the Bauschinger effect. This test program was statistically designed to enable a proper selection of form-aging parameters which would insure a minimum loss in compressive strength while giving maximum economy in production. The range of variables investigated are:

Temperature: 900-1100°F
Time: 5-35 minutes
Percent Stretch: 0-5%

RESULTS: The data obtained to date on this program are attached as Tables I, II, and III.

ESTIMATED COMPLETION DATE: October 1962.

TR 30-0839 (Continued)

TABLE I

RS-140 TITANIUM (.052" THICK)

CONTROL TESTS*

SHEET IDENT.	DIRECTION	F_{ty} KSI	F_{tu} KSI	% Elong.	F_{cy} KSI
A	Long	162.5 160.6	189.4 187.7	7.0 6.0	- 171.3
	Trans.	167.3 160.1	190.7 185.3	6.0 6.0	- 181.4
B	Long	162.9 168.8	202.3 195.8	- 4.0	172.0 171.8
	Trans.	164.0 166.7	194.0 190.9	6.0 9.0	179.2 -
C	Long.	164.3 169.0	191.9 192.2	- -	173.2 177.3
	Trans.	160.3 164.2	186.5 186.6	7.0 6.5	180.3 185.0
D	Long	165.1 170.2	194.6 198.2	6.5 6.5	175.2 178.6
	Trans	163.0 169.4	193.2 194.6	6.0 7.0	- 190.3
E	Long	173.3 168.8	206.5 203.5	4.5 5.0	179.8 172.5
	Trans	169.0 169.2	203.9 202.1	6.0 -	- -
F	Long	168.9 172.7	200.2 201.0	- -	179.8 175.4
	Trans	143.7 168.0	179.6 198.4	4.0 2.5	186.5 186.3

*Condition STA, 900°F for 6 hours aging cycle.

TR 30-0839 (Continued)

TABLE II
EFFECT OF PERCENT STRETCH AT 950°F
(30 MINUTES) ON COMPRESSIVE YIELD
STRENGTH OF RS-140 TITANIUM
SHEET

Sheet Identification	Percent Stretch	F_{cy} KSI
A-1	0	165.0
	0	161.8
	0	160.5
-3	0.6	164.0
	0.9	162.0
	0.5	-
	1.0	162.8
-4	2.3	154.2
	1.9	160.0
	2.3	154.6
	2.6	160.5
-5	4.2	156.0
	5.1	-
	5.9	162.2
	5.7	156.1
-6	3.4	161.2
	4.0	159.8
	4.1	158.5
	3.5	163.0
-7	3.0	158.2
	3.0	157.5
	2.7	-
	2.9	-

All tests in longitudinal direction.

TR 30-0839 (Continued)

TABLE III
EFFECT OF PERCENT STRETCH AT 950°F (10 minutes) ON COMPRESSIVE YIELD STRENGTH OF RS-140 TITANIUM SHEET

SHEET IDENTIFICATION	PERCENT STRETCH	F_{cy} KSI
A-5	0	164.2
6	0	170.0
7	0	167.0
8	0	167.9
9-C-1	3.7	157.2
-2	4.0	157.2
-3	3.7	154.6
-4	3.8	153.6
10-C-1	4.8	155.6
-2	4.4	158.2
-3	2.8	156.8
-4	2.4	155.8
11-C-1	2.7	156.2
-2	2.7	157.0
-3	2.1	162.2
-4	2.0	-
12-C-2	3.6	156.2
-3	2.7	156.0
13-C-2	3.6	154.7
-3	2.6	153.5
-4	2.6	153.2

All tests in longitudinal direction

TR 30-1939 (Corporate Funded)

TITLE: Material - 10 Ti-10Mo-80Cb at Room and Elevated Temperature - Mechanical Properties of

OBJECTIVE: The objective of this test program is to determine the usefulness of columbium alloys in aerospace vehicles at hypersonic speeds.

DISCUSSION: The use of refractory alloys in hypersonic vehicles is required by the high stagnation temperatures encountered upon reentry into the earth's atmosphere. Columbium alloys demonstrate high strength-to-weight ratios at temperature as well as possessing a fair amount of fabricability at room temperature. The alloy selected for this program is a commercially available alloy possessing an equal compromise of strength, fabricability, oxidation resistance and cost. The test program is outlined as follows:

1. Static Tests (Tensile)

   Notched and unnotched specimens will be run at RT, 1900°F, 2100°F, and 2300°F. Tests will be conducted in a vacuum after a 30 minute soak at test temperature. The notched specimens will have a centrally positioned hole to give a $K_T = 2.5$.

2. Creep and Stress Rupture

   Total strain will be recorded from initial loading to rupture at 1900°F and 2100°F. Stress levels to be used for this test will be determined from part 1 above.

3. Fatigue

   Smooth and notched ($K_T = 2.5$) specimens will be run in vacuum at test temperatures of 1900°F, 2100°F, and 2300°F. Stress levels will be determined from part 1 of this program.

RESULTS: No significant data has been generated to date.

ESTIMATED COMPLETION DATE: December 1962

TR 50-2045 (Corporate Funded)

TITLE: Process - Electroformed Co-W Alloy, Mechanical and Physical Properties, Determination

OBJECTIVE: To determine whether the 35% Co-65%W electroformed alloy initially investigated under a 1960 GD/FW sponsored corporate funded research program is suitable for structural aerospace applications.

DISCUSSION: Due to difficulties encountered with pitting and brittleness in the previous program, it will be necessary to determine the optimum anti-pitting and stress reducing agents as well as heat treatment for obtaining maximum stregth and ductility.

The program is being conducted as follows:

Phase I - Process Refinement

1. Several wetting and stress relieving agents will be evaluated for anti-pitting and lack of lamination in metallographs.
2. Various annealing cycles and solution heat treat with tempering cycles will be evaluated on pit-free specimens. Proof of strength and ductility will be based upon room temperature tensile tests, bend tests, metallographs and hardness tests. Tensile tests will be conducted in a vacuum at temperatures in the 1700°F to 2300°F range.

Phase II - Evaluation Testing

Electroformed test specimens will be prepared, based on the optimum bath as determined in Phase I, and tested as follows:

1. Oxidation resistance - to determine test temperature.
2. Tensile tests at -100°F to 2300°F
3. Salt spray
4. Abrasion resistance
5. Creep properties of 1800°F to 2300°F
6. Hot hardness at room temperature to 1800°F

RESULTS: Necessary chemicals have been ordered and recently received. Phase I is scheduled to start immediately.

ESTIMATED COMPLETION DATE: December 1962

TR 50-2090 (Corporate Funded)

TITLE: Development of High Temperature Coatings (Paint Type)

OBJECTIVE: The objective of this program is to complete the evaluation of a silicone-ceramic paint coating developed under a corporate funded program in 1961.

DISCUSSION: A spray type silicone-ceramic coating was developed in 1961 for elevated temperature applications. The coating was applied to several alloys that appear attractive for space applications and tested. These coated alloys performed satisfactorily when exposed to 1400°F in a vacuum of 10^{-7} mm of Hg with an emittance of 0.85.

A complete evaluation of the physical properties of this coating is proposed as a background for possible additional applications in the 1400°F to 2000°F regime.

This evaluation will consist of determining the maximum operational temperature of the coating by exposing test panels to temperature of from 1400°F to 2400°F. After determining the maximum temperature the coating is able to withstand, various physical properties will be determined, such as the following:

a. Thermal Shock
b. Adhesion
c. Flexibility
d. Fluid Immersion Resistance
e. Corrosion Resistance
f. Weather Resistance
g. Maximum exposure time at maximum temperature.

RESULTS: A control formulation has been compounded and applied to test specimens. Evaluation is scheduled to start in the very near future.

ESTIMATED COMPLETION DATE: December 1962

TR No. 30-2110 (Corporate Funded)

TITLE: High Temperature Coatings, Development and Evaluation of

OBJECTIVE: The object of this investigation is to develop and evaluate a slurry or spray-on intermetallic coating for elevated temperature oxidation protection of refractory metal alloys subjected to re-entry vehicle environments. This thermal environment will be 5 hours at 3300°F for a tantalum alloy and 20 hours at 2300°F for a columbium alloy.

DISCUSSION: General Dynamics/Fort Worth recent past efforts in the high temperature coating field has been primarily concerned with the pack cementation process and the reduction of metal halides. Variables such as time, temperature and elemental ratios were analyzed to optimize pack variables in processing.

Because of the encouraging results obtained by other investigators of this type of intermatallic spray-on coating FY1962 efforts is being directed towards upgrading or increasing the refractoriness of this type of coating. The basic approach is to modify the combining ratios of the constituents with elements of higher order.

RESULTS: Test specimens have been prepared and formulation studies are being conducted.

ESTIMATED COMPLETION DATE: December 1962

TR 30-2088 (Corporate Funded)

TITLE: New Joining, Materials and Processes - Columbium Brazing Alloys - Development of

OBJECTIVE: The objective of this program is to complete the development of a practical production brazing alloy for joining columbium and columbium alloys.

DISCUSSION: This is a continuation of previous research that has been conducted at GD/FW. The program will consist of the following steps:

A. A review and tabulation in summary form of all data resulting from previous test on experimental brazing alloys at GD/FW.

B. A selection of the most promising alloys for further evaluation.

C. Screening test of these selected alloys to complete metallurgical and mechanical tests not previously conducted. These tests may include:

1. Lap shear strength.
2. Microstructural analysis
3. Microhardness
4. Ductility
5. Remelt temperature
6. Oxidation rates
7. Sublimation rates

D: The best alloys (probably two but no more than four) will be selected as "production" brazing alloys for columbium. Further modification to add strengthening agents, oxidation retardants, wetting agents, melting point depressants, etc., will be made if necessary. This final step should result in the formulation of a "production-ready" brazing alloy with immediate commercial application.

RESULTS: The review and tabulation work has been started and the other steps are dependent upon the analysis of this data.

ESTIMATED COMPLETION DATE: September 1962.

TR 30-2089 (Corporate Funded)

TITLE: New Joining Materials and Processes - Diffusion Bonding - Investigation of

OBJECTIVE: The objective of this program is to conduct a preliminary investigation of the feasibility of producing structurally sound joints in metals by the solid state diffusion mechanism, and determine the effect of various variables on the diffusion phenomemon.

DISCUSSION: The basic investigation is directed along three avenues:

1. Diffusion joining of bare materials
2. Diffusion joining with "Transport Alloys" as developed by Westinghouse.
3. Diffusion joining with intermediate materials (thin films) in the interface to accelerate diffusion.

Two basic process limitations are established for this program for initial studies:

1. The study will concern itself with low pressures only (15 psi or less).
2. The study will not consider "hard" vacuums (better than 1×10^{-7}).

The basic intent in this program is to explore the feasibility of the porcess by conducting a series of screening tests to study potential processing variables and their interrelation. Small tee, lap shear and simulated sandwich specimens utilizing stainless steel, titanium and columbium will be used for these screening studies.

RESULTS: Limited screening tests have been conducted using small tee specimens and overlap shear specimens with D31 columbium alloy. Results have been promising using a proprietary pyrolytic decomposing "diffuzer" (GD/FW has coined the word "Diffuzer" to define intermediate materials used to accelerate diffusion) applied in the interface. Joints have been accomplished in an argon atmosphere at 2400°F for 30 minutes at less than 15 psi contact pressure.

ESTIMATED COMPLETION DATE: December 1962.

TR 50-2043 (Corporate Funded)

TITLE: New Joining Materials and Processes - Exothermic Brazing - Investigation of

OBJECTIVE: The objective of this program are to investigate and develop techniques for utilizing exothermic materials as a heat source for braze joining. The specific aim is the exothermic brazing of columbium alloy honeycomb sandwich construction.

DISCUSSION: The basic approach to be used is an adaption of the Goldschmidt "Thermite" process. In this process, low heat of formation oxides are reduced with powdered metals to form high heat of formation oxides accompanied by the release of energy (high heat). It is this heat in a relatively concentrated mass that will be used to attain braze-melt temperatures in sandwich panels and other joining applications.

Exothermic materials will be processed and tested for adaption to the process. These materials will be reacted in air, inert and static atmospheres and temperature surveys conducted to establish heat outputs and the variations from block to block. Modifications of thickness and/or chemical composition will make as necessary to obtain the proper heat source for a particular brazing temperature range.

In addition insulation and support materials needed during the brazing operation will be investigated. These materials will be required in order to provide the correct temperature at the braze line and to assure proper distribution of the heat.

Columbium alloy FS-82 has been chosen as the base material to be fabricated and brazed into honeycomb sandwich panels. The brazing alloy selection will be made from information obtained from a parallel research program. Specimens are to progress from size 1" x 1" to a maximum of 4" x 4" as processing problems such as cleaning, atmosphere control and hold down proessures are satisfactorily solved.

Structural test specimens will be fabricated using the best techniques developed. These specimens are expected to vary in size from 1/2" x 8" x 8" and perhaps as large as 1/2"x12" x 24".

RESULTS: Initial temperature surveys indicate that exothermic materials will create less heat in an argon or vacuum atmosphere than in air. These results will be further checked and modifications made as necessary. Studies of insulation and support materials have been started, but results are not yet available.

ESTIMATED COMPLETION DATE: December 1962

REA 14-61-592 (Corporate Funded)

TITLE: New Joining Materials and Processes - Electron Beam Welding of Columbium Alloy Sheet - Evaluation of

OBJECTIVE: The objective is to perform static and fatigue tests on specimens of D-31 columbium alloy welded by the electron beam process.

DISCUSSION: This is a joint program between General Dynamics/Fort Worth and General Dynamics/Astronautics. Basically, GD/FW will supply the D-31 columbium alloy sheet material and conduct all evaluation testing while GD/Astro will develop processing techniques and weld all test specimens.

Two gages of material are to be welded, .020 and .040 inch. Tensile tests, both longitudinal and transverse, at room and elevated temperature will be conducted. Metallurgical evaluations including hardness transverse will also be conducted.

RESULTS: Materials for the test specimens have been supplied to GD/Astro. Machine settings and process variable controls are now being established.

ESTIMATED COMPLETION DATE: August 1962.

TR 30-1997 (Corporate Funded)

TITLE: Welded Columbium Sandwich - Elevated Temperature - Test of

OBJECTIVE: The objective of this program is to evaluate welded columbium sandwich panels utilizing GD/FW developed DRC core at elevated temperature.

DISCUSSION: Two panels, size 1/2" x 12" x 12", will be fabricated utilizing .010"~~faces~~ and .006" double reversed corrugated core. Faces and core are to be Fansteel 82 Cb-33Ta-.7Zr resistance spot welded to each other.

These panels will be tested in column compression with a thermal gradient existing across their thickness. One-third of the predicted ultimate load will be applied and one face will be flash heated to 2200°F at a rate of 1000°F per minute and maintained for two minutes. The heat will then be removed and the panel allowed to return to a steady state temperature of not greater than 200°F. The load will be increased by 2000 psi and the heating-cooling cycle repeated. This cycling procedure will be continued, increasing the load each time. until failure occurs. Throughout the test the temperature of both faces will be recorded.

After the panels have been tested to failure, the unfailed portion of each will be cut into 2" x 3" edgewise compression specimens which will be tested at 2200°F and room temperature. In addition, a series of overlap spot welded tensile specimens will be tested at room temperature and 2200°F. These later specimens will be tested prior to the fabrication of the 12" x 12" panels in order to establish welding and processing techniques.

All elevated temperature tests are to be conducted in an inert atmosphere or in a vacuum to eliminate the necessity of protective coatings.

RESULTS: Test jigs and welding fixture are in work and materials are on order.

ESTIMATED COMPLETION DATE: November 1962

TR 30-2032 (Corporate Funded)

TITLE: Brazed Columbium Sandwich - Elevated Temperature - Test of

OBJECTIVE: The purpose of this program is to determine the compressive strength of a brazed columbium honeycomb sandwich panel at elevated temperature.

DISCUSSION: Two panels, size 1/2" x 12" x 12", will be brazed one with each of two different brazing alloys selected from a parallel development program. The panels will be composed of .010" faces and honeycomb core with 3/16" cell size and .002" foil ribbon. Both faces and core to be Fansteel 82 Cb-33Ta-.7Zr. The panels will be x-rayed to evaluate braze flow and fillet size; and measurements of the panel thickness, roughness and flatness recorded.

Each panel will be tested in column compression with a thermal gradient existing across their thickness. One-third of the predicted utlimate load will be applied and one face will be flash heated to 2200°F at a rate of 1000°F per minute and maintained for two minutes. The heat will then be removed and the panel allowed to return to a steady state temperature of not greater than 200°F. The load will be increased by 2000 psi and the heating-cooling cycle repeated. This cycling procedure will be continued, increasing the load each time.

After the panels have been tested to failure, the unfailed portion of each will be cut into 2" x 3" edgewise compresssion specimens. Tests at a steady state temperature of 2200°F and room temperature will then be conducted. Tensile specimens will be taken from the remainder of the panel and tested at 2200°F.

All elevated temperature tests will take place in an inert atmosphere or in a vacuum to eliminate the necessity of protective coatings.

RESULTS: The test jig for high temperature thermal shock testing is in the preliminary design stage. Evaluation of brazing alloys in order to select the most promising for this program is now in progress.

ESTIMATED COMPLETION DATE: November 1962

TR 10-1968 (Corporate Funded)

TITLE: Development of Chemical Etched Waffle Grid Beryllium Panel

OBJECTIVE: The objective of this program is to design, fabricate and test a waffle grid beryllium panel in order to provide a configuration which utilizes the stiffness-to-weight potential of beryllium.

DISCUSSION: A joint program was entered into between Brush Beryllium Corp., United States Chemical Milling Corp., and GD/FW. Each company to participate in the portion most directly related to its own field of interest. Brush Beryllium to furnish the beryllium plate, U. S. Chemical Milling to etch the panel and GD/FW to design and test the waffle grid panel.

Tests to be conducted include: (1) Tensile tests in both transverse and longitudinal directions to establish tensile ultimate, tensile yield, percent elongation and elastic modulus, (2) column compression test of a full scale panel and (3) shear test of the full scale panel.

A complete record of the material history, panel processing and fabrication techniques and test procedures and results are being maintained.

RESULTS: The panel has been designed, fabricated and the column compression test completed. Work on the shear test of the panel is now in progress.

The material received from Brush Beryllium was QMV hot rolled beryllium plate size 0.25" x 14" x 40". The plate had been stress annealed, surface ground and picked prior to shipment. Chemical composition was:

Be	99.3	Mg	0.024
BeO	1.63	Mn	0.010
Fe	0.1475	Ni	0.016
Si	0.028	Cr	0.009
Al	0.047	C	0.12

Tensile strength was:

	Brush	GD/FW
Tensile Ultimate		
Long.	70,400 psi	70,500 psi
Trans	70,800 psi	69,300 psi
Tensile Yield		
Long	53,200 psi	53,500 psi
Trans.	54,000 psi	52,600 psi
Percent Elgonation		
Long	6.75%	6.0%
Trans.	7.7	6.0%

TR 10-1968 (Continued)

The column compression test instrumentaion consists of strain gages and dial deflection gages. The data from this test however has not been analyzed.

ESTIMATED COMPLETION DATE: August 1962.

TR 50-2006 (Corporate Funded)

TITLE: Investigation of New Unconventional Polymerization Techniques and Development of Semi Inorganic Polymers

OBJECTIVE: To investigate by literature search and laboratory experiments:

(1) Unconventional polymerization techniques such as the use of liquid metals, fused salts, and high temperature fluids as polymerization media which could yield high temperature polymers with acceptable processing characteristics.

(2) Polymerization of semi-inorganic polymers with inherent high temperature properties.

DISCUSSION: Work will be directed toward finding a low density low melting, high boiling, non-reactive media suitable for use as a polymerization media. Materials to be considered include hydrocarbon wax (in oxygen free atmosphere), silicone oil, camphor, abitol, and hydrocarbon oil (in oxygen free atmosphere). Some of the possible monomers to be investigated for polymerization in selecting a media are:

(a) Stearylmethacrylate
(b) Ethylacrylate
(c) Laurglmethacrylate
(d) Butylacrylate
(e) Methylmethacrylate
(f) Octyl-Decylmethacrylate

Monomers to be utilized for possible thermal resistant polymers are:

(a) B-Triphenylborazole
(b) B-Trimethylborazole
(c) Hexamethylborazole
(d) Aluminum Phenoxide
(e) Aluminum Oxinate
(f) Aluminum Isopropoxide
(g) P-phenylenediamine
(h) Benzidene
(i) Melamine
(j) Triallyl Isocyanurate

A series of tests such as molecular weight, curing agents, water resistance, fuel resistance, etc., will be used to screen promising polymers.

TR 50-2006 (Continued)

The use of conventional polymerization methods will be utilized should it be determined that a promising polymer can be more easily synthesized in this manner.

RESULTS: Tests are in progress.

ESTIMATED COMPLETION DATE: December 1962.

TR 50-1898 (Funded Under the B-58 Contract)

TITLE: Evaluation of Vacuum Post-Cure to Improve Weathering Resistance of Windshield Interlayer Material (Type K Silicone)

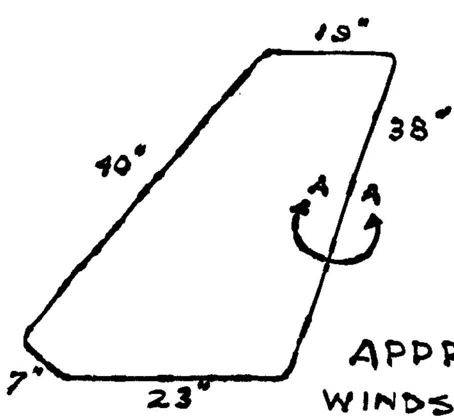
OBJECTIVE: To determine if an extended post-cure under vacuum will improve the weathering resistance of a windshield containing Type K silicone interlayer. The windshield will receive the post-cure after it has been processed by the normal production method used by the manufacturer (Libbey-Owens-Ford).

DISCUSSION: Two production B-58 windshields (General Dynamics Drawing 4B-1132) will be processed as below prior to the accelerated weathering exposure. A third windshield with no post-cure will be used as a control. The windshield will be exposed to accelerated weathering until visual degradation (crazing) of the interlayer has occurred.

Post-cure procedure: The windshields will be placed in a container suitable for post-curing the windshields for 48 hours at 300°F while under at least 25" Hg vacuum. Volatiles evolved from the windshields during postcure will be collected and analyzed as to composition.

Accelerated weathering procedure: The two windshields and a control will be exposed in a sealed container which has a soda-lime glass window as one side. The container will be situated so that the windshield inside is exposed to sunlight. Each morning, the container will be filled with a 10% sulphur dioxide and 100% relative humidity atmosphere. Each evening the container shall be purged with fresh air.

Windshield details:



APPROX. WINDSHIELD SIZE & SHAPE

EDGE DETAIL
SECT. A-A

RESULTS: Tests have not been started.

ESTIMATED COMPLETION DATE: July 1962

TR 50-2019 (Corporate Funded)

TITLE: Effect of 700°F and Vacuum on Properties of Systems and Safety Materials

OBJECTIVE: Determine change in properties of selected materials as a function of time at 700°F and pressures of 10^{-1} mm Hg to 10^{-6} mm Hg.

DISCUSSION: Work will provide information on materials under extreme conditions for support of future projects. Materials to be tested are:

(1) Dynabond 132 adhesive (General Dynamics developed structural adhesive)

(2) RTV Silicone rubber - Dow Corning Corp., - Identification not established by Dow.

(3) Narmco X-278, Narmco Materials Division, Costa Mesa, California

Adhesives will be tested in shear using MIL-A-005090D overlap shear specimens and procedures except adherends will be RS-140 annealed titanium. The RTV will be tested for adhesion using ASTM D 429-58 butt tension specimens except rubber thickness will be .12 to .25 inch. Adherends will be RS-140 annealed titanium.

At least 5 specimens of each material will be tested at room temperature after exposure to each of the following conditions:

(1) Temperature; 700°F
(2) Time; immediately after reaching 700°F and after 0.1 hour, 5 hours, and 10 hours at 700°F.
(3) Pressure; ambient, 10^{-1} mm Hg. 10^{-3} mm Hg and 10^{-6} mm Hg.

Adherends will be cleaned as follows:

(1) hand wipe with methyl-ethyl-ketone
(2) Trichloroethylene vapor degrease
(3) Pickle for 30 seconds in room temperature water solution of Nitric acid (15% by volume of 70% HNO_3 solution) and Hydrofluoric acid (3% by volume of 50% HF solution).
(4) rinse in tap water at room temperature
(5) rinse for two minutes in room temperature water solution of trisodium phosphate (50 gms/liter of solution) sodium fluoride (8.9 gms/liter of solution) Hydrofluoric acid -50% solution (26 milliliters/liter of solution).

TR 50-2019 (Continued)

(6) rinse in room temperature tap water.
(7) soak in 150°F tap water for 15 minutes
(8) spray with distilled water and air dry.

Adhesives will be applied and cured 2 hours at 350°F under 50 psi. The RTV will be applied and cured 7 days at room temperature under contact pressure.

RESULTS: Tests have not been started.

ESTIMATED COMPLETION DATE: September 1962.

TR 50-1538 (Funded under the B-58 Contract)

TITLE: JP-4 Fuel - Bacteria, Fungus, and Hydrogen Gas - Test For

OBJECTIVE: To determine the extent of microorganism activity in B-58 integral fuel tanks and to determine the hydrogen gas concentration in the air space of the B-58 integral fuel tanks.

DISCUSSION: The purpose of this program is to obtain samples of fuel and/or water from the bottom of the fuel tanks of several B-58 airplanes and to obtain samples from the air space above the fuel in the same fuel tanks included in the fuel sampling survey. The test fuel and/or water samples will be examined visually with a microscope for evidence of microorganism growth and will be used to inoculate Bushnell-Haas medium and Potato Infusion Agar. The cultures will be examined periodically for microorganism growth. The concentration of hydrogen gas will be determined using a Mass Spectrograph.

RESULTS: No evidence of microorganism activity or unusual concentration of hydrogen gas was detected.

ESTIMATED COMPLETION DATE: October 1962

TR 50-1371 (Funded under the B-58 Contract)

TITLE: Material - Prepare Catalyst for Silicone Leading Edge Sealant

OBJECTIVE: To develop a past type catalyst for use with Dow Corning QC-2-0046 silicone sealant.

DISCUSSION: The purpose of this test program is to investigate possible liquid carriers which might be used in the development of a suitable paste type catalyst for Dow Corning QC-2-0046 silicone leading edge sealant. The Dow Corning sealant is a one part material which cures when exposed to air. However, when used in thick sections, it does not cure satisfactorily. General Dynamics/Fort Worth developed a powder type catalyst, CS-48, to facilitate the curing of QC-2-0046. Because it is a powder, CS-48 catalyst is difficult to mix with the sealant.

Several liquid carriers will be selected for the investigation. Any of the carriers which prove to be compatible with CS-48, will be further investigated to determine if the resultant paste catalyst is suitable for use with QC-2-0046 sealant.

Compression set and hardness, after exposure to 180°F, 220°F and 260°F, will be measured. Also, any tendency of the cured sealant to sponge at 260°F and a simulated altitude of 50,000 feet will be investigated.

RESULTS: Nine liquid carriers have been investigated. Of the nine, two have proven satisfactory: DC-200 silicone compound and uncatalyzed XF-10042 silicone polymer.

ESTIMATED COMPLETION DATE: July 1962

TR 50-1970 (Corporate Funded)

TITLE: Sealants - Composite Metal-Fiber O-Rings and Flexible Metal Seal - For High Temperature Use

OBJECTIVE: To develop a fuel sealing system for future aircraft designed for high speed flight including space and re-entry operations in the temperature range of -100°F to 1200°F.

DISCUSSION: The purpose of this program is to investigate the sealing properties of composite metal-fiber O-rings and flexible metal seals. Testing will first be performed at room temperature with air pressure. If a satisfactory seal is obtained under those conditions, testing will be performed with air pressure at -100°F and 1200°F. If that testing proves successful, testing will be performed with pressurized fuel and then at the high and low temperatures.

RESULTS: The work performed has been to make a preliminary evaluation of a composite metal-fiber O-ring supplied through a request to ASD by the Armour Research Foundation of Chicago, Illinois. The O-ring was placed between two machined steel plates in a hydraulic press with a 40,000 pound load and with 20 psi internal pressure used to check for leakage. During that test, only one very small leak occurred.

ESTIMATED COMPLETION DATE: December 1962

TR 50-1514 (Funded Under the B-58 Contract)

TITLE: Material - Grease, Wheel Bearing - Braycote 660 AMS or Royco 60 AMS - Properties of

OBJECTIVE: The purpose of these tests are to determine if Braycote 660 AMS or Royco 60 AMS wheel bearing grease meets the added requirements of GD/FW Specification FMS 0169, a modification of specification MIL-G-25760A.

DISCUSSION: The B-58 MLG wheel bearings required a lubricant which would prevent premature failures of bearings due to shock loading. Tests conducted with B-58 aircraft demonstrated such a capability of Braycote 660 AMS Grease. Since the base grease is approved under MIL-G-25760A, it was necessary to conduct tests to determine the effects of the addition of 10% microsize molybdenum disulphide on the high temperature performance, water washout, evaporation, oil separation, apparent viscosity at -40°F, and foreign particle count.

RESULTS: Braycote 660 AMS or Royco 60 AMS exhibited the following properties, when tested:

(a) water washout per FTMS 791 Method 3252 - 7%
(b) evaporation per ASTM D 972 - 5.77%
(c) oil separation per FTMS 791, Method 321 - 6.11%
(d) apparent Viscosity @ 40°F per ASTM D 1072 - 9980 poises
(e) high temperature performance per CRCL35 - 108 hours
(f) foreign particles - Not yet determined

These preliminary tests indicate that the grease will meet all the requirements of GD/FW Specification FMS-0169, except for high temperature performance. The requirement for 400 hours (minimum) duration at 350°F did not take into consideration the property changes of the base grease by the addition of the molybdenum disulphide. Since the grease did perform satisfactorily in the B-58 main landing gear wheel bearings, this requirement will be reduced to 100 hours.

ESTIMATED COMPLETION DATE: July 1962.

TR 50-2003 (Funded under the B-58 Contract)

TITLE: Process - Aluminum Alloy, 7075-T6 (Bare) affects of Varying Pretreatments for Solid Film Lubricant Application on Corrosion Susceptability.

OBJECTIVE: These tests were performed to determine the effects of varying the pretreatments required for solid film lubricants and to determine the optimum point during the pretreatment processing when the solid film lubricant is to be applied.

DISCUSSION: Premature failure of a solid film lubricant coated 7075T6 aluminum alloy part of the B-58 due to corrosion caused this investigation. GD/FW Process Specification FPS-0058 requires that solid film lubricants be applied to unsealed anodic coatings immediately after the anodizing operation. These corroded parts had been hard anodized and sealed, then had the solid film lubricant applied.

A test program was established to determine (1) if the selection of hard anodize plus solid film was the optimum combination for corrosion protection, (2) if the sealing of the anodic coating prior to solid film lubrication was detrimental; and (3) if sulphuric acid anodize or a chemical film conversion coating afforded better protection against corrosion.

Standard 3" x 10" x .040" bare 7075T6 aluminum alloys were pretreated as given below, and then coated with Alpha Molykote X106 solid film lubricant. The panels were subjected to 20% salt spray per FTMS 151 for 250 hours and for 500 hours. After exposure, the panels were cut into standard tensile bars. Ultimate tensile strength and elongations were determined for each of the combinations.

Pretreatment Schedule for Aluminum Alloy Test Panels.

1. Hard Anodized, by Southwest Metal Finishing, Tulsa, Oklahoma, then solid film lubricant coated by GD/FW.
2. Hard Anodized and sealed by Southwest Metal Finishing, Tulsa, Oklahoma, then solid film lubricant coated by GD/FW.
3. Hard Anodized, but not sealed, and then solid film lubricant coated by Southwest Metal Finishing, Tulsa, Oklahoma.

TR 50-2003 (Continued)

4. Sulphuric Acid Anaodized, but not sealed, per MIL-A-8625, Type II, and then solid film lubricant coated by Southwest Metal Finishing Tulsa, Oklahoma.

5. Chemical Film treated per MIL-C-5541, and then solid film lubricant coated by Southwest Metal Finishing, Tulsa, Oklahoma

RESULTS: Preliminary test data indicates that those aluminum alloy test panels which had been given the hard anodic coating, but not sealed, then coated immediately with Alpha Molykote X106, exhibited the least reduction in tensile strength and elongation.

ESTIMATED COMPLETION DATE: July 1962.

TR 51-0915 (Funded under the B-58 contract)

TITLE: Material - Solid Film Lubricants - Resistance to MIL-H-8446, MIL-H-5606, and MIL-L-7808 Under Dynamic Loading.

OBJECTIVE: The purpose of this test is to determine which solid film lubricant (Alpha Molykote X-106 and Thermo M, and GD/FW X-38) has the best resistance to MIL-H-8446 and MIL-O-5606 hydraulic fluids and to MIL-L-7808 lubricating oil when tested under dynamic loading.

DISCUSSION: Specification MIL-L-25504 for solid film lubricants utilizes a tape test to determine the apparent resistance of solid film lubricants to various aircraft fluids. Standard Timken test races will be prepared and mounted on the LFW-1 test machine. A container of the test fluid will be positioned under the specimen in such a manner that the lower portion of the race will be in contact with the fluid. The machine will be loaded while the race is rotating, until failure of the coating occurs. A newly coated race will be mounted and the setup repeated. The applied load on the hanger will be reduced by one pound. The time to failure will be determined.

NOTE: Thermo M will not be evaluated because it is no longer commercially available. Another coating will be selected for this test.

RESULTS: Preliminary tests conducted on X-38 solid film lubricant indicate that under dynamic loading the wear life is drastically reduced when the lubricant is contaminated with certain types of aircraft fluids.

ESTIMATED COMPLETION DATE: October 1962.

TR 50-1224 (Funded Under the B-58 Contract)

TITLE: 4340 (260-292 KSI) Phosphatized Hydrogen Embrittlement Wear

OBJECTIVE: These tests were conducted to determine whether parts heat treated above 220 KSI should be pretreated using a 12.5 or a 60 point (total acid) phosphate solution (MIL-P-16232, Type M), and to determine the effects of this pretreatment on hydrogen embrittlement and wear life and corrosion resistance of test races coated with Alpha Molykote X106 (MIL-L-25504) and GD/FW X38 solid film lubricants.

DISCUSSION: Preliminary tests previously conducted on notched tensile bars of 4340 steel heat treated to 260-292 KSI indicated that the 60 point (total acid) phosphate solution caused a reduction in the sustained load carrying capabilities of the specimens.

However, in order to gain corrosion protection of 4340 steel which is to be coated with a solid film lubricant, it is necessary to apply a phosphate coating pretreatment prior to application of the lubricant. Baking cycles usually associated with curing solid film lubricants relieve some of the effects of the hydrogen embrittlement introduced by the phosphate coating treatment. The following tests were conducted:

1. Sustained Load Tests

   Heat treated notched tensile bars were pretreated with 12.5 point and 60 point (total acid) phosphate coatings. Some were prebaked only, others were coated with solid film lubricants, X106 (baked for 90 minutes) and X38 (baked for 2 hours at 260 plus 12 hours at 350°F). Specimens were loaded initially to 75% of notched tensile stress. Those which carried the load for 120 hours were then loaded to 90% for an additional time until failure occurred or until 380 hours had elapsed.

2. Corrosion Resistance and Wear Life Tests

   Test specimens were fabricated from SAE 4340 steel heat treated to 260-292 KSI to the standard Timken T54146 test cup configuration. The test cups were pretreated with 12.5 point and 60 point (total acid) phosphate coatings and top coated with X106 and X-38 solid film lubricants, each given their required bake cure cycle.

TR 50-1224 (Continued)

(a) Corrosion Resistance

Prepared test cups were subjected to 20% Salt spray per FTMS 151, Method 811.1 for 192 hours.

(b) Wear life tests

Prepared test cups were subjected to oscillating and rotating wear life when loaded to 63,000 psi.

RESULTS: Preliminary test results indicate the following:

1. Sustained Loads

Those test bars which had been given the 60 point (total acid) phosphate pretreatment followed by X-38 solid film with its scheduled bakecycle satisfactorily withstood the 75% stress level, but gave erratic results when stressed to 90%. Other treated specimens, when stressed to the 75% level experienced erratic failures probably due to the shorter bake cycle employed which did not remove the effects of hydrogen embrittlement caused by the pretreatment.

2. Corrosion Resistance

Test cups which were pretreated with the 60 point phosphate coating followed by X-38 solid film lubricant application showed less effects of corrosion after 192 hours of exposure to 20% salt spray than did those which were pretreated with the 12.5 point phosphate coating and then coated with X-106 or X-38 solid film lubricants.

3. Oscillating and Rotational Wear Life

The strength of the pretreatment solution did not appreciably effect the wear life characteristics of the solid film lubricants tested.

ESTIMATED COMPLETION DATE: August 1962

TR 50-1736 (Funded under the B-58 Contract)

TITLE: Control Surfaces - Elevon Hinge and Actuator Pins - Reclamation of

OBJECT: These tests were conducted to determine if hinge pins, fabricated from SAE 4340 steel, heat treated to 260-292 KSI, could have the previously applied solid film lubricant removed and then reprocessed with an improved solid film lubricant.

DISCUSSION: Standard Timken Cup Races were fabricated from SAE 4340 steel and heat treated to 260-292 KSI. They were pretreated with a 12.5 point (total acid) phosphate coating. Alpha Molykote X106 and GD/FW X38 solid film lubricants were applied to the outer surfaces of test races. (X-106 was the coating previously used on the hinge pins, but was replaced because of its loss of wear life capability when contaminated with aircraft fluids.) The X106 coating and its pretreatment were removed by blasting with ground corn cob. The stripped races were retreated with the phosphate coating and X-38 solid film lubricant. Oscillating wear life tests were conducted on the originally treated X-38 races and on the races retreated with X-38.

RESULTS: Preliminary tests conducted on the test races indicate that the wear life capabilities of test races either originally treated with X-38 or those which had a previous lubricant stripped and then retreated with X-38 would be comparable.

Indications are that soft grit blasting, such as ground corn cob, is an effective means of removing previously applied solid film lubricants, without metal removal, and that hinge pins could be satisfactorily stripped of their previously applied solid film lubricant and be recoated with GD/FW X-38 solid film lubricant.

ESTIMATED COMPLETION DATE: October 1962

TR 50-1971 (Corporate Funded)

TITLE: Material - Lubricant, Solid Film, High Temperatur
Evaluation of

OBJECTIVE: The object of this research is to continue la
experiments on a high temperature resistant solid fi
ricant developed under a corporate funded program in

DISCUSSION: A high temperature resistant solid film lubri
developed in 1961, was applied to standard Timken Cup
races fabricated from a tool steel with good hot hard
capability. Rotational wear characteristics were det
at 1150°F under intermediate loads applied by means o
shoes fabricated from the same steel.

Additional tests will be conducted to determine the e
of varying the composition of the coating in comparis
the original composition as follows:

(a) Effects of temperature on coefficient of frictio
starting speed, and wear life at -65°F and at
1150°F.

(b) Effects of vacuum (10^{-4} mm Hg) at room temperat
coefficient of friction, starting speed. and we

RESULTS: Preliminary tests conducted indicate that the
temperature solid film lubricant exhibits exceptiona
life characteristics at 1150°F [illegible] subjected to in
late loads.

ESTIMATED COMPLETION DATE. December 1962